DEVELOPMENT OF FINNED HEAT REMOVAL SYSTEM FOR MOTORCYCLE EXHAUST PIPE

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ABSTRACT

This paper reviews fin heat exchanger in the removal of heat that arises from motorcycle exhaust pipe resulting in varying degree of burns, affecting both the user and passenger when in contact with it. The minimum temperature that can cause a burn in a finite amount of time is starting from 44^{0}C to 51^{0}C. In this study copper pipe and aluminum fins were used where the heat transfer rate needed to be improved and they were constructed separately and attached to the surface by bolt and nut. Analysis to determine the number of fins and optimum diameter of fin that would reasonably enhance the heat transfer rate from the exhaust pipe to reduce risk of burns when in contact with it were carried out. Analysis was carried out to know the rate of heat transfer from the exhaust pipe (without Fins) and also the projected rate of heat transfer from the fin array, which resulted in an effectiveness i.e. an increase in exhaust heat transfer rate by a factor of 2.5. Fabrication of the fin array was carried out with the use of 1mm aluminum material and 4mm copper pipe as the base plate (the lighter the aluminum fin the faster the cooling rate and better heat transfer rate is achieved). The fin array is very portable and may be easily unfastened and tried on other exhaust pipes, as parts were joined solely by bolt and nut. The risk of receiving serious burns when accidentally in contacts with it, is reduced.

Keywords: Exhaust pipe, Burns, High Temperature, Fins, Analysis

INTRODUCTION

Motorcycle use IC engines, which have huge amount of energy loss in the form of heat (**A. S. Mate** 2017). The minimum temperature that can cause a burn in a finite amount of time is starting from 44^{0}C to 51^{0}C, the rate of burn increases by a factor of approximately four times with each Celsius degree risen.(thermal burn-wikipedia).

The aim of this work is to reduce thermal (temperature) of motorcycles exhaust pipe burns popularly called Okada in local Nigerian parlance for intra-city transportation. By controlling the exhaust gas temperature, normal operating conditions can be achieved and it also enhances the performance of the engine. (A. S. Mate et al, 2017). The study covers Nigeria as a territorial area while drawing specific examples from Lagos, which is regarded as the bustling commercial nerve centre of Nigeria and other cities within the country. The nature of Okada transport business in these places portrays to a large extent, the pattern of use in the rest of the country. It is only in few instances that one can find minor variations (Oyesiku, 2002: 28). Motorcycles remains the major means of commercial transport system which have the highest percentage in intra-city transport in Nigeria because Motorcycle is a reliable, convenient and cheap means of transportation in the developing countries. It has become a preferred means of transportation ; Oladipo, 2002 stated in his study that there is no state in Nigeria where motorcycle is not been used due to its availability at various parks and within the cities attracting patronage among people from all facet of life which explains its growing number of users in Nigeria. Due to the increasing number of users and growing preference for motorcycle, it has become very necessary to consider its effect with respect to the likely injuries that may be caused by its (motorcycle) use. One of the primary injury that is commonly sustained from the use of motorcycle is Motorcycle burn; which is mostly sustained by the user and/or passengers of motorcycle through direct contact with overheated parts of the motorcycle. Burns resulting from contact with exhaust pipe and other parts of the motorcycle have different degree of severity in which some of the cases are not debilitating, although severe cases of other injuries resulting from motorcycle road crash can cause long-term and sometimes permanent effects. An abrasion like that which occurs from road crash can remove several layers of skin, exposing deeper layers of skin, muscle, and other tissues to external detrimental factors. In severe cases like this, they are better referred to as third degree burns. Severe cases also have other risks involved, such as infection or complications which can result in death. (Matzavakis, 2005). The temperature of the bent surface of exhaust pipe through which exhaust gases are flowing, falls between the range of 150°C to 180°C which poses a serious threat to motorcycle users when there is a direct contact, thus, by attaching a copper pipe and aluminum fins to this bent exhaust pipe using bolt and nut, the temperature of the exhaust pipe will reduce. (Çengel **2002**).

MATERIALS AND METHODS

Design Analysis

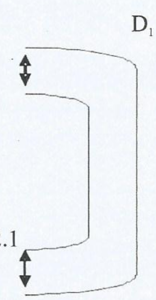
This part is a very important aspect in the fabrication of the heat management system. It shows the analysis of the heat transfer rate of exhaust pipe and the expected increase in heat transfer rate of the exhaust pipe with the addition of fin array and hence the performance (effectiveness), of the fin array.

Heat Transfer From The Tube (without fin)

Analysis: In the case of no fins, heat transfer from the tube per meter of its Length is determined from Newton's law of cooling to be

$A_{no\ fin} = \pi D_1 L$ *2.11*

$Q_{no\ fin} = hA_{no\ fin}(T_b - T\infty)$ 2.12



Heat Transfer From Single Fin

Heat transfer from single fin is determined by Newton's law of cooling as

$A_{fin} = 2\pi(r_2^2 - r_1^2) + 2\pi r_2 t$ 2.1

$Q_{fin} = ?_{fin} \times hA_{fin}(T_b - T_8)$ 214

Where 'A_{fin}' is the heat transfer surface area of fin and 'h' is the convection heat transfer coefficient temperatures 'T_b' and '$T\infty$' are fixed by design considerations, 'η_{fin}' is the efficiency of the circular fins attached to a circular tube.

Heat Transfer From The Unfinned Portion Of The Tube

Heat transfer from the unfinned portion of the tube isdetermined by

$A_{unfin} = \pi D_1 S$.. 215

$Q_{unfin} = hA_{unfin}(T_b - T_8)$...216

Number of fins and the total heat transfer from the finned exhaust pipe isdetermined by

$Q_{total} = n\ (Q_{fin} + Q_{un\ fin})$ 217

The Increase In Heat Transfer From The Exhaust Pipe

The increase in heat transfer from the exhaust pipe as a result of the addition of fins is determined by

$Q_{increase} = Q_{total} - Q_{no\ fin}$ 2.18

Surface Area Of The Frustum Of A Cone

The surface area of the frustum of a cone is given as

$$A_{no\,fin} = \pi(R + r)\sqrt{(R - r)^2 + h^2} \qquad \dots\dots\dots\dots\dots\dots\dots\dots 2.19$$

Where 'h' is the height, 'R' is the bigger radius 'r' is the smaller radius

Parameters Obtained from Bajaj Motorcycle

Diameter of bigger part of the exhaust pipe (frustum)	= 100mm
Diameter of smaller part of the exhaust pipe (frustum)	= 80mm
Length of bigger part of the exhaust pipe for the (frustum)	= 500mm
Bent exhaust cylindrical pipe (smaller) diameter	= 30mm
Length of bent exhaust cylindrical exhaust pipe	= 300mm
Exhaust pipe temperature	= 180°C
Fin material thermal conductivity	= 186 W/m°C
Diameter of aluminum fin (outer)	= 120mm
Diameter of aluminum fin (inner)	= 38mm
Thickness of aluminum fin	= 1mm
Diameter of copper pipe (outer)	= 38mm
Diameter of copper pipe (inner)	= 30mm
Thickness of copper pipe	= 4mm
Length of copper pipe	= 140mm
Fin spacing (S)	= 7mm
Fin number	= 19
$T\infty$	= 25°C
Coefficient of heat transfer	= 40W/m2.°C

Design Calculation

Determination of Area of the copper pipe

Diameter of the copper pipe (outer) = 38mm = 0.038m

Diameter of the copper pipe (inner) = 30mm = 0.03m

Thickness of the copper pipe = 4mm = 0.004m

From equation 3.13 area of the copper pipe is given as

$$A_{cop} = 2\pi(r_2^2 - r_1^2)\,2\pi r_2 t$$

$$A_{cop} = 0.001333m^2$$

Determination of Area of the aluminum fin

Diameter of circular aluminum fin (outer) = 120mm = 0.12m

Diameter of circular aluminum fin (inner) = 38mm = 0.038m

Thickness of circular aluminum fin = 1mm = 0.001m

$$A_{fin} = 2\pi(r_2^2 - r_1^2)\,2\pi r_2 t$$

$$A_{fin} = 0.02078m^2$$

Determination of Area of the bigger exhaust pipe (frustum)

Length of the bigger exhaust pipe (frustum) = 500mm = 0.5m

Diameter of the bigger exhaust pipe (top) = 100mm = 0.1m

Diameter of the bigger exhaust pipe (bottom) = 80mm = 0.08m

From equation 3.19 area of the bigger exhaust pipe (frustum) is given as

$A_{no\ fin}$ $\pi(R + r)\sqrt{(R - r)^2} + h^2$

$= 0.1415m^2$

Determination of Area of the smaller exhaust pipe (frustum)

Length of the smaller exhaust pipe (frustum)	= 10mm	= 0.01m
Diameter of the smaller exhaust pipe (top)	= 80mm	= 0.08m
Diameter of the smaller exhaust pipe (bottom)	= 30mm	= 0.03m

$A_{no\ fin} = \pi(R + r)\sqrt{(R - r)^2} + h^2$

$= 0.00465m$

Determination of Area of the cylindrical bend exhaust pipe (most injurious part)

Length of the cylindrical pipe	= 300mm	= 0.3m
Diameter of the cylindrical pipe	=30mm	=0.03m

From equation 3.11 area of the cylindrical exhaust pipe is given as

$A_{no\ fin} = \pi DL$

$= 0.0282m^2$

Total surface area of exhaust pipe = area of the bigger exhaust pipe + area of the smaller exhaust pipe + area of the cylindrical pipe

$= 0.1415 + 0.00465 + 0.0282 \qquad = 0.174m^2$

Determination of Heat transfer from the exhaust pipe (i.e without fins) is calculated from newton's law of cooling

$Q_{no\ fin} = hA_{no\ fin}(T_b - T\infty)$

$= 1078.8W$

The Efficiency of the aluminum circular fins attached to a circular bend exhaust pipe is calculated as follows:

$L = \frac{1}{2}(D_2 - D_1)$

$= 0.041m$

$= \frac{r2 + \frac{1}{2}t}{r1} = \frac{0.06 + \frac{1}{2}x0.001}{0.019} = 3.184$

$= L + \frac{1}{2}t\sqrt{\frac{h}{kt}}$

$\eta_{fin} = \frac{3.184 - 0.0483}{3.183} = 0.98$

Determination of Heat transfer from single fin is calculated as follows

$A_{fin} = 2\pi(r_2^2 - r_1^2) + 2\pi r_2 t$

$= 0.021m^2$

Area of the circular copper pipe

$A_{cop} = 2\pi(r_2^2 - r_1^2) + 2\pi r_2 t$

$= 0.00133m^2$

Total area for fin = area of aluminum circular fin + area of circular copper pipe

$A_{fin} = 0.021 + 0.00133$

$= 0.02233m^2$

$Q_{fin} = \eta_{fin}$ x $hA_{fin}(T_b - T_8)$

$= 136.4W$

Determination of Heat transfer from a single unfinned portion of the exhaust pipe

$A_{un\ fin} = \pi DS$

$= 0.00084m^2$

$Q_{un\ fin} = hA_{un\ fin}(T_b - T_8)$

$= 5.3W$

There are 19 fins and so the total heat transfer from the finned exhaust pipeis

$Q_{total} = n\ (Q_{fin} + Q_{un\ fin})$

$= 2692.3W$

Therefore, the increase in heat transfer from the exhaust pipe as a result of the addition of fins

$Q_{increase} = Q_{total} - Q_{no\ fin}$

$= 2692.3 - 1078.8 \qquad = 1613.5W$

The overall effectiveness $= \frac{Qtotal}{Qunfin} = \frac{2692.3}{1078.8} = 2.5W$

RESULT AND DISCUSSION

RESULTS

The grouped fin was tested on a Bajaj bike (boxer motorcycle) and Digital Thermometer was used as follows:

The temperature of the exhaust pipe of Bajaj motorcycle was first taken before starting up the machine was 30^{0}C. The motorcycle was started and the temperature of the exhaust pipe taken after 340sec was 118^{0}C (without fin). The copper pipe (frame) and aluminum fins array were coupled to the bent exhaust pipe of the motorcycle and the temperature was taken again after 180sec, the temperature of the copper pipe (frame) was 49.9^{0}C, that of the aluminum fins was 31.4^{0}C. While the motorcycle exhaust pipe was 52.5^{0}C. With the attachment of the copper pipe and aluminum fin for the duration of 340sec was taken, the temperature read 70.1^{0}C for copper pipe (frame), 36.1^{0}C for aluminum fins and 74^{0}C for the motorcycle exhaust pipe. All this was taken when the motorcycle was at idle work i.e. the Motorcycle did not take a trip from the testing spot. When the Motorcycle finally moved for 5minutes without the fins, the bent exhaust pipe temperature (most injurious part) read 125°C and when the motorcycle moved for 8minutes without fins the temperature was 150^{0}C. When the copper pipe (frame) and the aluminum fins is attached to the bent exhaust pipe it read 66°C for the same duration of movement (5minutes) and it also allow to moved for another 10minutes with fins the temperature was 48^{0}C. A better change was noticed when compared with the motorcycle idle work, due to fluid motion. With additional number of fins it is expected that the heat transfer rate would improve and the temperature obtained would far more reduce.

EXPERIMENTAL RESULT

Table 3.1: Temperature Profile of Motorcycle Exhaust Pipe at Idle Mode

The designed system was made to run at three different Speeds and the results are as follows:

Speed (rpm)	Time (sec)	Sinks temp (t_1)^{0}C	Source temp (t_2)^0	Exhaust temp(t_3)^0
2000	180	31.4	49.9	52.5
	340	36.1	70.1	74
	485	37.2	81.1	83.9
	560	39.9	91.2	92.3
4000	115	31.5	50.9	54.4
	225	36.7	69.8	74.1
	265	35.4	68.1	72.7
	300	37.9	71.0	73.1
	360	40.2	72.9	77.7
6000	100	32.5	58.3	60.8
	130	36.2	68.1	71.9
	146	37.8	78.5	82.7
	170	39.2	80.5	87.3

Fabrication Process

Fabrication entails all process involved in the production of the fin array. It involved marking out operation, welding, drilling and bolting of the parts to be coupled. The fin was marked out on the Aluminum sheet and was cut with the use of guilloten shear, chisel, scriber, hammer and the following were cut out: the circular fins (into two semi circle). The copper pipe was marked out and machined to the actual diameter and length (into two semi circle). Aluminum fin seated on the copper pipe and both clamped to the bent part of the exhaust pipe (most injurious part) by means of bolt and nut.

MATERIAL SELECTION: Aluminum and Copper materials were chosen for the manufacturing of the heat management system, because of low cost, corrosion resistance and weight. The system comprises of fins array coupled to a copper frame and fitted to the exhaust pipe by means of bolt and nut.

(i) Heat source and heat sink:

- A heat source is an object that produces or radiates heat.

1) Copper heat source

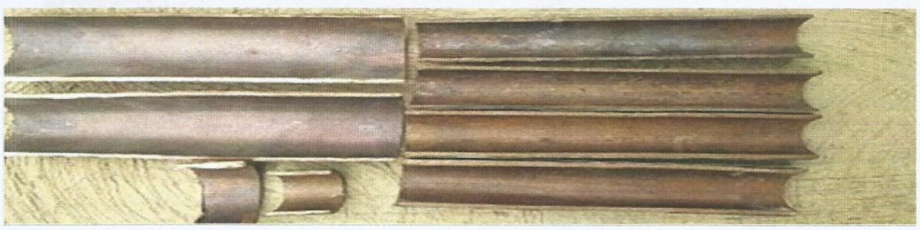


Figure 1. Copper heat source fabricate for the present study.

Copper has the high thermal conductivity and melting point easy to weld at silencer bent pipe which transmit heat to the aluminum fins. Therefore in this experimental setup, copper pipe as a heat source at hot side is used. The copper pipe is been attached to the hot junctions of the exhaust bent pipe of I.C. engine carrying the hot exhaust gases. This copper pipe have a smooth surface, two semicircle copper pipe with length 140mm, diameter of 30mm with thickness of 4mm acts as a heat source.

- A heat sink is an object that absorbs and dissipates heat from another object using thermal contact.

2) Aluminum heat sink

Figure 2. Aluminum heat sink fabricated for the present study

The aluminum heat sink is used in the present investigation. It contains number of fins cooled by air cooling system. The temperature of aluminum heat sink (cold side) is the room temperature (around 25 to 30°C). The aluminum heat sinks fins is 19 in numbers with outer diameter 120mm, inner diameter 38mm with 1.0mm thickness which is shown in fig.2. Two heat sinks are used in the experimental setup. Aluminum heat sink is used because it has high thermal conductivity it is easily available, low cost, light weight and side is properly attached

(ii) Digital Thermometer

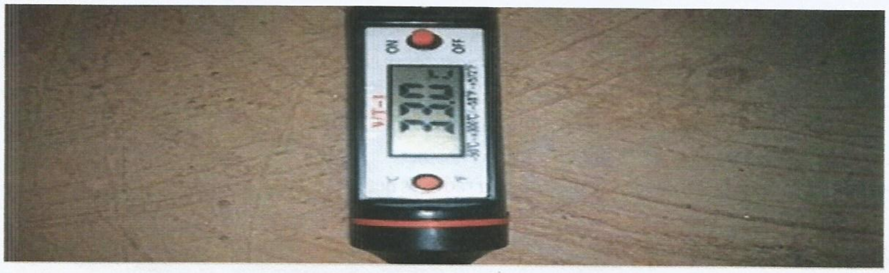
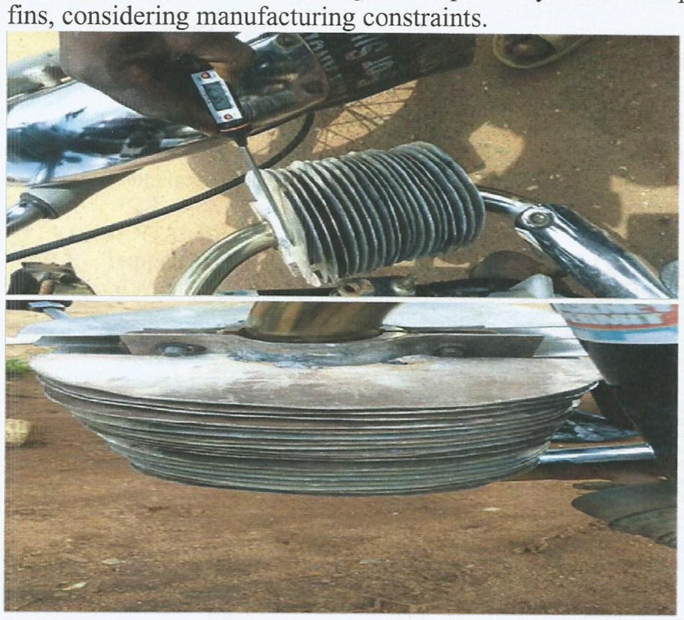


Figure 3. Digital Thermometer

Digital Thermometer: This experimental setup has one digital thermometers, it is use to measure the temperature of the hot junction before and after the copper pipe and aluminum fins are used. The range of the digital thermometer is -50˚c to 300˚c and the thermometers have contact type probe.

Fin Geometries

The performance of a fin heat exchanger is determined, among other things, by the geometry of the fins. The most common fin configurations are the fins with circular, rectangular, trapezoidal or triangular shape . Any desired shape can be given to the fins, considering manufacturing constraints.



Conclusion

The primary objective for the fabrication of heat exchanger fins to enhance the heat transfer rate from Motorcycle exhaust pipe to prevent exhaust burns when accidentally in contact with it has been achieved to a reasonable degree. Special notice was given to factors that greatly affect the performance of the fin, like; the optimum fin diameter and thermal contact resistance, to make sure of preferred result. For fabrication purpose, the most effective and economical choice of material was chosen considering the weight, the thermal conductivity, cost and corrosion resistance. The price of a unit of this project might not appeal to many, but when produced in mass the price would reduce and it would be affordable by all. Conclusively, the copper pipe (frame) and the aluminum fins array would improve the rate of heat transfer from the exhaust pipe, so that the risk of receiving serious burns when accidentally in contacts with it, is reduced drastically.

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